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A spatial interaction model with land use and land value

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1. Introduction

Cities seem to be living organisms without perceivable brain. The idea that some smart brain would be able to address the sustainable development of cities and territories is as old as the humanity. Nevertheless, the possibility that ICT can gather enough data and produce useful and trustable indicators (Ben Sta, 2017) for innovative urban management is just appearing, arguably as a conjunction of four forces (Angelidou, 2015): smart government, smart transport, smart buildings and smart utilities. The problem is that those indicators mostly address central managers and not to normal citizens that, as common stakeholders, base their decisions on market prices and institutional, environmental and infrastructural constraints.

The purpose of this paper is to show that, with models for complex systems applied to cities and its environments, technologies and institutions, it is possible to estimate shadow prices that reveal the scarcities that can inform central managers of governments, transport systems, major buildings and large scale utility providers. More than that, they could provide prices for decentralized decision makers addressing the problem of market failures on common laws, resources and infrastructures, while not putting all the cards and information on central managers supposedly immune to policy failures.

This exercise focus on land use and land value that are the result of the interactions between ecosystems and civilizations through technologies and institutions (Bowler et al., 2003; Pinto-Correia & Kristensen, 2013; Taylor, 1988). Technologies and institutions mirrored in the two backbones of smart cities: ICTs and Innovative Governance. The proposal is to calibrate a model of complex systems of city to evaluate the effect on employment, land use and land and real estate values (wealth) that result from changes in the environment (Climate Change), in the economy (External Relations), in the technology (accessibility) or in the institutions (Land Use Planning).

Various approaches try to explain changes in and land use patterns. Some assume that demand for land result from culture, preferences and motivations (Antrop, 2005; van Berkel & Verburg, 2011). Others focus the attention on markets, accessibilities and population (Alonso, 1964; Glaeser, 2005; O'Sullivan, 2009; von Thünen, 1826). Van Schrojenstein Lantman, Verburg, Bregt, & Geertman (2011) take into account technological and environmental constraints.

Gravity models of spatial interaction, for a long time reported in the well rooted in economics, geography and statistical theory are able to describe and predict the flow of people, goods and information across space (Roy & Thill, 2004; Wilson, 2010). With gravity models of spatial interaction, it is possible to enlarge the knowledge and expertise on transports (Earlander & Stewart, 1990; Evans, 1976; Hyman, 1969), commerce and marketing (Bergstrand, 1985; Deardorff, 1998; Huff, 1964) and demography migration (Plane, 1984). Finally, when activities have a footprint, these approaches can also be associated to land use (Anderson, 1979; Batty, 1976; Haynes & Fotheringham, 1984; Isard, 1975; Millonen & Luoma, 1999). Spatial Interaction Models can act as decision support systems (Irwin & Geoghegan, 2001) based on cost benefit analysis based on hedonic prices associated to the calibrated attraction factors of the gravity-based spatial interaction model that are closely related to the bid-rents of land constraints (Borba & Dentinho, 2016).

The aim of this paper is to develop for an urban system and its surroundings a spatial interaction model with land use to understand how regulatory, technological and environmental constraints plus basic employment and accessibility, influence employment, population, commuting, land use, land values. The application of the model to Terceira Island in the Azores for climate change and economic scenarios demonstrates its capacity to generated systemic cost benefit analysis of external shocks adding to the existing literature on urban integrated models and cost-benefit analysis in urban systems. Research questions are mainly operational. What model can interconnect the economy and the environment at an urban scale? What tool can serve to accomplish cost benefit evaluation of urban systems? Does the model apply to different urban areas? Does the system provide useful information for decentralized decision makers?

The development of the work involved different phases. Section 2, proposes a reformulation of former models (Borba & Dentinho, 2016; Gonçalves & Dentinho, 2007; Silveira & Dentinho, 2010) to include the relation between bid-rents and land prices for urban and rural areas. Section 3 refers to data collection and the calibration of the model that explains land use patterns and bid rents as a function of the basic employment, accessibilities and land aptitudes. Section 4 presented a hedonic regression relating the values of land and property with the bid-rents estimated by the Spatial Interaction Model with Land Use. Section 5 presents the estimates of land uses and land values associated to climate change scenarios. Section 6 advances the conclusions and

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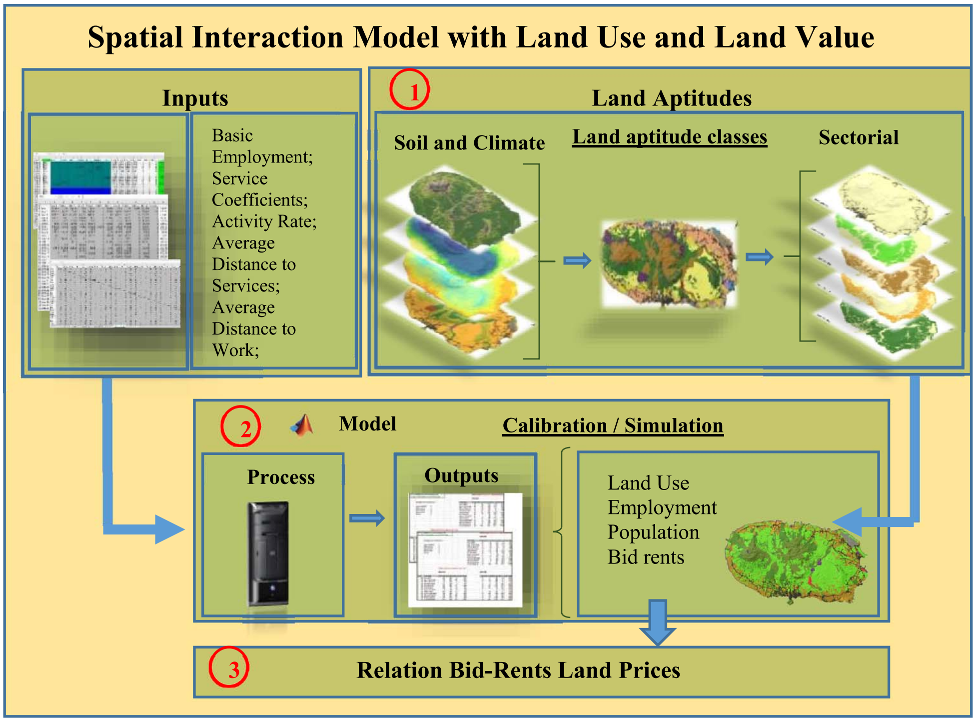

Fig. 1. Spatial interaction model with land use and land value.

prospects for future work.

2. Spatial interaction model with land use and land values

The spatial interaction model with land use and land values is a gravity-based Garin/Lowry-type model (Garin, 1966; Lowry, 1964) with footprints for each activity and land use constraints. The model generates residents, employment per sector, land use and land value by zones and land aptitude classes resulting from exogenous variable such as the basic employment per sector and zone, resident and employment footprints, land availability by class aptitude, accessibility, average residence-employment per sector and residence-services per sector distances.

As presented in Fig. 1 the Spatial Interaction Model with Land Use and Land Value. In Module 1 environmental data is treated using a GIS framework to get land aptitudes for the various sectors. Module 2 includes the model described above and programmed in MATLAB. Module 3 is an econometric hedonic price model that related land prices with the bid-rents of the Spatial Interaction Model with Land calibrated in Module 2.

The Design of Land Classes results from combining land aptitudes for different sectors generating classes of land aptitude with similar capabilities to receive the various sectors and design them in a map.

The model to calibrate and simulate assumes that the spatial interaction of activity in one sector located in one origin i and which employees reside in one destination j is positively related with the attraction on destination j (V_j/W_j) and negatively related to the distance between origin and destination (d_{ij}) controlled by the impedance coefficient α. A higher value W_j on a specified zone signifies that the attraction (V_j/W_j) must be reduced to guarantee that all demand on that zone/land class fits into the available land; W_j reflects ultimately higher real estate values and are related to the value of the bid-rent of land availability of land class/zone (j). V_j provides scale to (land class/zones) with different dimensions. Summing up all the commuting movements from employment to residence for each residence and multiplying by the inverse of the activity rate (r) we obtain the Population in each land class/zone.

On the other hand, the activities generated for each sector (k) in zone/land class (i) serves the population that lives in the various zones/land classes positively related with the attraction on destination j (V_j/W_j) and negatively related to the distance between origin and destination (d_{ij}) controlled by the impedance coefficients per sector $\beta(k)$. Summing all the shopping movements from residence to services for each residence and multiplying by the various service coefficient (s_k) we obtain the employment in each land class/zone.

Defining the elements of the matrices $[A]$ and $[B]$ as:

$$[A_{i(kj)}] = \frac{r.\ V_j/W_j.\ e^{-\alpha d_{ij}}}{\sum_{j=1}^{m} r.\ V_j/W_j.\ \ e^{-\alpha d_{ij}}} \text{ for all } k \tag{1}$$

$$[B_{(jk)i}] = \frac{s_k.\ V_i/W_i.\ e^{-\beta(k) d_{ij}}}{\sum_{i=1}^{m} s_k.\ V_i/W_i.\ \ e^{-\beta(k) d_{ij}}} \tag{2}$$

The endogenous variables (P_j and E_i) result from the exogenous variable E_b, using matrices $[A]$, $[B]$ and the identity matrix I_M:

$$[E] = \{I_M - [A][B]\}^{-1}.\ \ [E_b] \tag{3}$$

$$[P] = \{I_M - [A][B]\}^{-1}.\ \ [E_b]\,[A] \tag{4}$$

To secure that the residence-employment commuting costs and residence-services shopping costs from the model are equal to the real average costs, the model is iteratively calibrated for parameters α and $\beta(k)$ until the model average costs are similar to the real average costs. V_i/W_i values are also iteratively calibrated to guarantee the accomplishment of constraints that the demand for space in each zone/class is lower or equal than the space available. The V_i/W_i calibrated attraction values can also be interpreted as bid rents (ω_i) (Roy & Thill, 2004; Wilson, 2010). The bid-rent is complementary to the transportation costs and is given by the formula:

$$\omega_i = -\left(ln\,\frac{1}{\left(\frac{V_i}{W_i}\right)}\right) \tag{5}$$

The model code is in MATLAB 2013a (Mathworks, Natick, United States). The attrition parameters α and β (k) and the bid-rents are adjusted by Hyman's calibration method (Hyman, 1969).

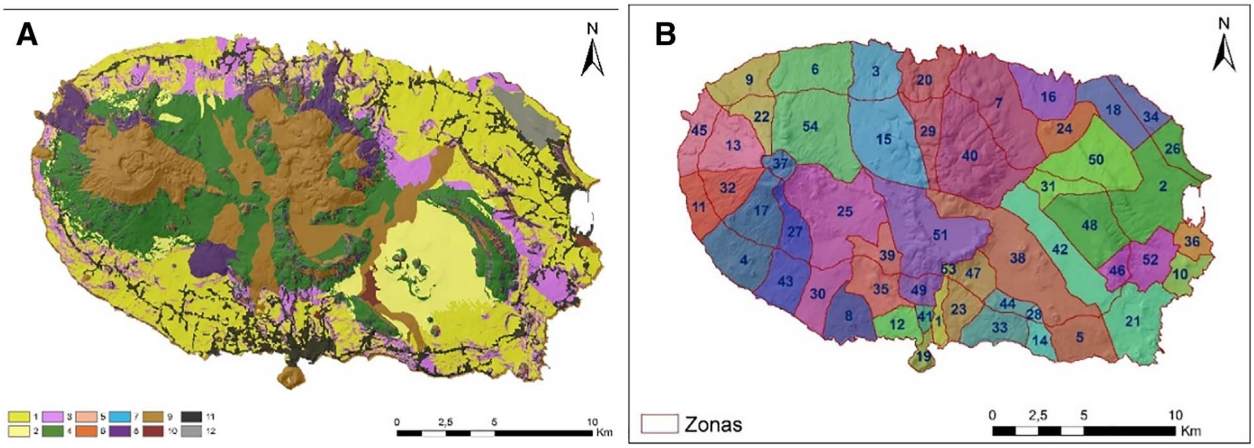

Fig. 2. Map of land classes and delimitation of 54 + 1 zones in Terceira Island.

3. Data collection and model calibration of the model

Terceira is an Island with 400 km^2 and 56,000 residents located in the Middle of North Atlantic 1500 km from Lisbon in Portugal and 3000 Km from Halifax in Canada. The American Air Field from 1950′s until 2010, dairy products since 1960′s, the support of the Portuguese and European administrations since 1980′s, and tourism strengthen after the introduction of low cost flights in 2016 constitute the economic base of the island (Haddad, Silva, Porsse, & Dentinho, 2015).

The island has 54 zones divided according to the administrative division and the altitude because the highest zones of the parishes are not apt for residences due to bad climate conditions. The 55th zone is external and used to facilitate the calibration of the model (Fig. 2 (b)).

The combination of land aptitudes for different sectors (Table 1) generates 12 classes of land aptitude that can be mapped (Fig. 2 (a)).

Population and employment per sector and per zone are from the Census of 2011 (INE, 2012). Sectors of activity, very much grouped according to the respective footprint, are the following: Urban that included the retired personnel multiplied by the activity rate (K1), Industrial (K2), Lajes Military Base (K3), Horticulture (K4), Agriculture (K5), Animal Husbandry (K6) and Forest (K7). The estimates of Basic Employment (Annex 2) come from the Indices of Herfindahl and parameter for the relation between non basic employment per sector and population (sk), average distance to shop by sector and commute from residence, footprint per employment were obtained from the land use maps and regional statistics supporting the calibration of the model (Table 2).

Fig. 3 show the main results from the calibration of the model with a map of bid-rents and a map of land use. Interestingly land class 2 located between the two main cities have the highest bid rents in rural areas. On the other hand, the urban area in Angra has higher bid-rents than the urban area in the different parts of the island.

Table 1
Possible uses and land aptitude classes.

Class	Urban	Industrial	Base	Horticulture	Agriculture	Pasture	Forest
1	–	–	–	X	X	X	X
2	–	–	–	–	X	X	X
3	–	–	–	X	–	X	X
4	–	–	–	–	–	X	X
5	–	–	–	X	X	–	X
6	–	–	–	–	X	–	X
7	–	–	–	X	–	–	X
8	–	–	–	–	–	–	X
9	–	–	–	–	–	–	–
10	–	X	–	–	–	–	–
11	–	–	–	–	–	–	–
12	X	–	X	–	–	–	–

Table 2
Land use by activity and calibrated parameters.

Sector of activity	Land use (ha)	sk	Average distance	Hectares per employment	Calibrated α and β_k
Urban	2700	0,195723	12	0,019478	0,0462
Industrial	315	0,006202	11	0,095663	0,0639
Lajes	482	0,001152	10	0,116667	0,0849
Horticulture	500	0,000408	10	6,373517	0,0986
Agriculture	3127	0,000904	15	12,63454	0,0151
Pasture	19,740	0,002126	17	13,24856	0,0113
Forest	3700	0,000248	20	54,84687	0,0088
Residential			7,4	0,06	0,2622
Other areas	9464			0,00	
Total	40,028	0,206762			
Inverse of activity rate		1,961525			

4. Hedonic regression relating land values with the bid-rents

Based on 145 inquiry on the value of 362 parcels of land in Terceira Island and on the inquiry on the values of urban dwellings made by Ana Rodrigues (2016) it was possible to estimate the hedonic regression of the Natural Logarithm of those values with the values of the bid-rents of the model in point 3. The control variables used were land contract, proximity of roads, urban infrastructures, land classes and land uses.

Results from four models presented in Table 3 are quite interesting. On the one hand, the explanatory capacity of the bid-rents estimated in the Spatial Interaction Model is high. That: (1) validates the Spatial Interaction Model; (2) indicates the existence of strong spatial interaction; and (3), responding to the purposed of the paper, justifies the use of the bid-rent of the spatial interaction model as a good proxy for the value of real estate. On the other hand, with the exception of land classes that have not a large area, all land classes have a significate impact on the value of land. Finally land uses, with the exception of Horticulture that implies extra investments on land, and tenancy do not affect the value of land, which reaffirms rent theory (von Thünen, 1826) that estates that it is the characteristics of land and accessibility to markets land that define its use and value.

5. Land uses and land values associated to climate change scenarios

Looking at the scheme of Fig. 1 the integrated model Spatial Interaction Model (2), and Hedonic Land Price Model (3), serve to

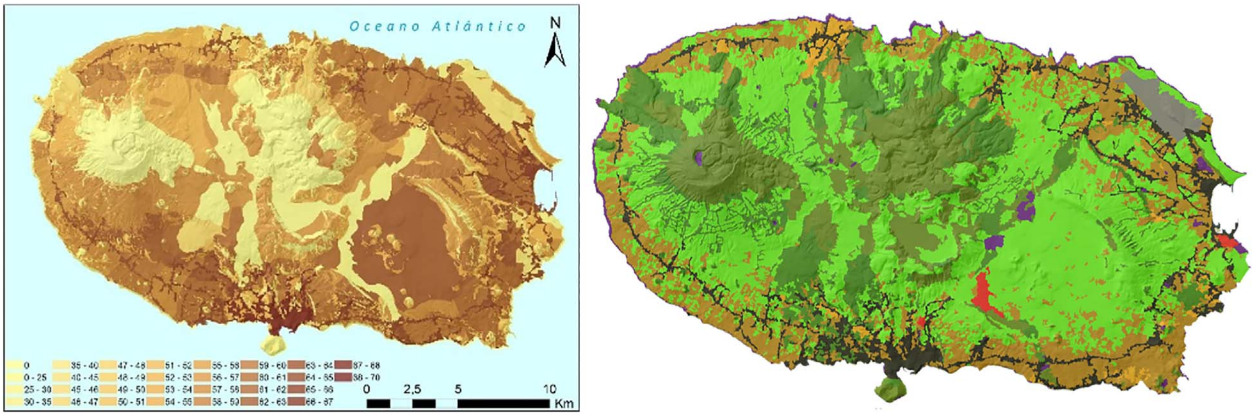

Fig. 3. Maps of land prices and land uses.

estimate the impact of changes in the list of inputs. Changes in Basic Employment associated to regional economic performance, modifications in service coefficients when labour productivity and consumption preferences evolve, adjustment of service footprints when there are alterations in land productivity, shifts on the activity rate that evolve with demography, and variations in the average distance travelled to work and to shopping related to accessibility. All of these changes would lead to a different equilibrium found by the calibration of the parameters α and $\beta(k)$ until the model average costs are similar to the real average costs and the bidrents ω_i. The same adjustment of the parameters is due when the Land Aptitudes in Model 1 of Fig. 1 vary as a result from Climate Change. This paper focus on the impacts of climate change because the study of the impact of the inputs that did not required the disaggregation of zones per land aptitude was already done in a former paper (Borba & Dentinho, 2016).

Climate change scenarios IPCC (2014), were spatialized for Terceira Island based on the model CIELO (Azevedo, Pereira, & Itier, 1999) for scenarios EC_Earth RCP 4.5 and RCP 8.5 for the years 2010/2039, 2040/2069, 2070/2099. The simulation of temperature and precipitation for the various locations of Terceira Island facilitate the redesign of land class maps and the changes in Land aptitudes that are implicit. The hectares suitable for urban, industrial, Base, Agriculture and Forest uses are do not suffer from climate change. Nevertheless, there is a strong reduction in the area with aptitude for pasture that although compensated by a strong increase in the area with aptitude for horticulture will not, per see, push up external demand for horticulture (Table 4).

These changes in land aptitudes without modifications in external demand for the various sectors would lead to a different equilibrium between demand and supply of land establish by new parameters α and $\beta(k)$ and new bid rents (ω_i). Then, using the new estimated bid rents and the regression estimated in Section 4 it is possible to calculate that the value lost with scenario RCP8.5 (2070/2090) is 231 million euros for rural areas and 524 million for urban and rural areas.

6. Conclusion

Responding to the question of interconnecting the economy with the environment at an urban scale, we consider the city as involving both the urban area and the rural area that feeds it and that is true directly from most cities that base their economy on the transformation of spatially rooted natural resources and capabilities.

Concerning the question of doing accomplishing cost benefit

Table 3
Hedonic regression relating land values with bid-rents.

	Model 1			Model 2			Model 3			Model 4		
	$R^2 \approx 0{,}844$			$R^2 \approx 0{,}843$			$R^2 \approx 0{,}844$			$R^2 \approx 0{,}842$		
	F ≈ 119,160			F ≈ 134,669			F ≈ 155,505			F ≈ 168,859		
	Sig. < 0,0001			Sig. < 0,0001			Sig. < 0,0001			Sig. < 0,0001		
	Beta	*t*	Sig.	Beta	*t*	Sig.	Beta	T	Sig.	Beta	T	Sig.
(Constant)	− 0,024	− 0,010	0,992	− 0,172	− 0,072	0,943	− 0,213	− 0,089	0,929	− 0,586	− 0,285	0,776
Bid rents	12,814	3881	0,000	12,974	3929	0,000	12,992	3939	0,000	13,470	4631	0,000
Tenant owner	− 0,076	− 1232	0,219									
Owner	0,082	0,625	0,532									
Road	0,798	5257	0,000	0,797	5248	0,000	0,826	5521	0,000	0,850	6732	0,000
Urban area	0,328	3806	0,000	0,336	3933	0,000	0,318	3797	0,000	0,316	3790	0,000
Infra	0,315	2586	0,010	0,326	2689	0,007	0,334	2763	0,006	0,335	2774	0,006
Horticulture	0,465	3404	0,001	0,433	3206	0,001	0,499	4163	0,000	0,501	4191	0,000
Agriculture	− 0,035	− 0,435	0,664	− 0,039	− 0,482	0,630						
Florest	− 0,345	− 1214	0,225	− 0,322	− 1153	0,249						
Classe11	3511	17,244	0,000	3529	17,592	0,000	3545	17,734	0,000	3530	18,227	0,000
Classe1	0,416	4324	0,000	0,415	4321	0,000	0,392	4469	0,000	0,396	4568	0,000
Classe2	0,338	4066	0,000	0,332	4008	0,000	0,326	4001	0,000	0,328	4057	0,000
Classe3	0,521	2703	0,007	0,548	2863	0,004	0,478	2628	0,009	0,498	2929	0,004
Classe5	0,422	4192	0,000	0,434	4316	0,000	0,412	4544	0,000	0,415	4608	0,000
Classe7	3054	3978	0,000	3199	4216	0,000	3029	4074	0,000	3139	4814	0,000
Classe8	0,168	0,502	0,616	0,191	0,571	0,568	− 0,074	− 0,308	0,758			
Classe9	1687	2053	0,041	1716	2088	0,037	1598	1960	0,051	1730	2502	0,013

Table 4
Area of land aptitudes for RCP4.5 e RCP8.5 and for 2039, 2069 and for 2099.

	Urban	Industrial	Base	Horticulture	Agriculture	Pasture	Forest
Scenario (2011)	20,807	150	468	9824	13,687	19,659	28,343
RCP4.5 (2039)	20,807	150	468	14,450	13,687	25,446	28,343
RCP4.5 (2069)	20,807	150	468	18,241	13,687	20,152	28,343
RCP4.5 (2099)	20,807	150	468	20,453	13,687	19,335	28,343
RCP8.5 (2039)	20,807	150	468	15,322	13,687	25,446	28,343
RCP8.5 (2069)	20,807	150	468	20,529	13,687	20,775	28,343
RCP8.5 (2099)	20,807	150	468	23,686	13,687	17,678	28,343

evaluation of urban systems, we were able to create an interconnected model that linking the bid rents of the spatial interaction model with land use with land prices can estimate the change in the total value of the urban system associated to changes in the model inputs and land aptitudes.

Finally, regarding smart cities we could divert the focus from the concreteness of the flows of people, information and material that supposedly feed data to serve some smart managers as proposed by the literature on smart cities (Gonzalez, 2015; Angelidou, 2015; Bennett et al., 2016; Ben Sta, 2017). In fact, with the exercise we show that we are able to provide useful information for decentralized decision makers very much related to real estate prices that result from different economic, political, technological and environmental scenarios.

The paper improves the Spatial Interaction Models with Land Use developed by models (Borba & Dentinho, 2016; Gonçalves & Dentinho, 2007; Silveira & Dentinho, 2010) to add the relation between bid-rents and land prices both for urban and rural areas. The use of MATLAB allowed the consideration of more areas and more sectors and more accurate bid rents results associated to the hedonic model estimated in 4.

Future work should include the inclusion of dynamic elements in the Spatial Interaction Model namely by assuming that change in urban areas are associated to the pressure of the bid rents.

Annex 1. Distribution of population and employment by activity (INE, 2012)

Name	Zone	Population	Employment per sector							
			K1	K2	K3	K4	K5	K6	K7	Total
Conceição I	1	3717	1636	18	4	0	2	3	0	1664
Santa Cruz I	2	5341	2315	24	15		47	27	2	2433
Biscoitos I	3	1424	692	8	1	11	11	17	2	743
Santa Bárbara I	4	1187	589	7	1	2	25	25	1	650
Porto Judeu I	5	2501	1189	13	3	2	14	26	0	1247
Altares I	6	901	439	5	1	4	28	39	1	517
Agualva I	7	1432	686	8	1	4	35	58	4	797
São Mateus I	8	3757	1723	19	4	2	31	2	1	1780
Raminho I	9	565	286	3	1	0	17	18	1	326
Porto Martins i	10	1001	479	5	1	6	7	1	1	499
Doze Ribeiras I	11	513	262	3	1	0	6	19	0	291
São Pedro I	12	3460	1500	16	3	1	9	0	1	1529
Serreta II	13	0	0	0	0	0	0	19	3	22
Feteira I	14	1239	576	6	1	3	0	6	0	593
Biscoitos II	15	0	0	0	0	0	0	41	1	42
Vila Nova I	16	1678	785	9	2	2	47	1	1	845
Santa Bárbara II	17	87	32	1	0	0	0	39	1	73
Lajes I	18	3657	1592	17	3	1	27	0	0	1639
Sé I	19	955	417	4	1	0	0	0	0	423
Quatro Ribeiras I	20	394	198	2	0	1	10	16	3	231
São Sebastião I	21	2096	976	11	2	4	22	36	2	1053
Raminho II	22	0	0	0	0	0	0	17	1	19
São Bento I	23	2000	894	25	2	1	6	16	0	944
São Brás I	24	1088	496	5	1	4	21	8	0	535
São Bartolomeu II	25	0	0	0	0	0	1	77	4	81
Santa Cruz III	26	1292	565	6	148	0	10	0	1	730
Cinco Ribeiras II	27	0	0	0	0	0	1	30	0	31
Feteira II	28	0	0	0	0	0	0	1	0	1
Quatro Ribeiras II	29	0	0	0	0	0	0	3	1	4
São Bartolomeu I	30	1983	926	10	2	1	23	13	1	977
Fontinhas II	31	0	0	0	0	0	0	24	0	25
Doze Ribeiras II	32	0	0	0	0	0	0	25	1	25
Ribeirinha I	33	2684	1240	14	3	1	7	20	1	1286
Lajes II	34	87	40	0	538	0	5	0	0	584

Terra Chã I	35	2915	1298	14	3	2	11	15	1	1345
Cabo da Praia I	36	712	325	42	1	0	12	0	0	380
Santa Bárbara III	37	0	0	0	0	0	0	0	0	0
Porto Judeu II	38	0	0	65	0	0	5	111	2	183
Terra Chã II	39	0	0	0	0	0	0	13	1	14
Agualva II	40	0	0	0	0	0	0	39	7	46
Santa Luzia I	41	2755	1211	13	3	0	3	1	0	1231
São Sebastião II	42	0	0	0	0	0	4	75	1	79
Cinco Ribeiras I	43	704	338	4	1	1	24	17	0	385
Ribeirinha II	44	0	0	9	0	0	0	8	0	16
Serreta I	45	335	177	2	0	0	0	14	3	197
Fonte do Bastardo II	46	0	0	0	0	0	0	15	1	16
São Bento II	47	0	0	42	0	0	1	20	1	63
Santa Cruz II	48	57	29	0	0	0	2	64	2	98
Posto Santo I	49	1048	468	5	1	1	3	12	1	491
Fontinhas I	50	1594	717	8	1	2	36	30	1	795
Posto Santo II	51	0	0	0	0	0	0	55	4	59
Fonte do Bastardo I	52	1278	592	7	1	15	9	20	1	645
Conceição II	53	0	0	0	0	0	0	1	0	1
Altares II	54	0	0	0	0	0	1	84	2	86
Total Employment			25,686		450	750	77	523	1222	28,772
Total Population		56,437								

K1 – urban; K2 – industrial; K3 – Lajes; K4 – horticulture; K5 – agriculture; K6 – pasture; K7 – forest.

Annex 2. Distribution of basic employment by sector of activity

Name	Zone	Basic employment per sector of							
		K1	K2	K3	K4	K5	K6	K7	Total
Conceição I	1	964,2	0,0	0,0	0,2	2,0	2,7	0,0	969,2
Santa Cruz I	2	1385,4	0,0	10,0	1,7	43,9	24,0	1,4	1466,3
Biscoitos I	3	369,4	0,0	0,0	10,8	10,8	15,2	1,3	407,5
Santa Bárbara I	4	320,6	0,0	0,0	0,8	23,7	21,7	0,3	367,1
Porto Judeu I	5	648,8	0,0	0,0	0,8	12,3	22,9	0,0	684,8
Altares I	6	233,7	0,0	0,0	3,4	25,6	35,3	0,5	298,5
Agualva I	7	371,5	0,0	0,0	3,2	32,6	51,5	3,5	462,2
São Mateus I	8	974,6	0,0	0,0	0,2	29,2	1,4	0,3	1005,7
Raminho I	9	146,6	0,0	0,0	0,1	15,4	15,4	1,2	178,6
Porto Martins i	10	259,7	0,0	0,0	5,4	6,3	0,9	0,4	272,8
Doze Ribeiras I	11	133,1	0,0	0,0	0,3	5,4	17,0	0,1	155,8
São Pedro I	12	897,5	0,0	0,0	0,0	8,5	0,0	0,6	906,7
Serreta II	13	0,0	0,0	0,0	0,0	0,0	17,2	2,9	20,1
Feteira I	14	321,4	0,0	0,0	2,6	0,3	5,3	0,3	329,9
Biscoitos II	15	0,0	0,0	0,0	0,0	0,0	37,7	1,1	38,8
Vila Nova I	16	435,3	0,0	0,0	0,3	44,8	0,5	0,2	481,1
Santa Bárbara II	17	9,9	0,0	0,0	0,0	0,0	36,1	0,9	46,8
Lajes I	18	948,6	0,0	0,0	0,0	25,2	0,0	0,1	973,9
Sé I	19	247,7	0,0	0,0	0,0	0,2	0,0	0,0	247,9
Quatro Ribeiras I	20	102,2	0,0	0,0	0,2	9,2	14,9	2,5	129,1
São Sebastião I	21	543,7	0,0	0,0	1,9	20,0	31,9	2,0	599,6
Raminho II	22	0,0	0,0	0,0	0,0	0,0	16,0	1,1	17,2
São Bento I	23	518,8	8,5	0,0	0,6	4,6	13,9	0,2	546,6
São Brás I	24	282,2	0,0	0,0	3,0	19,5	6,7	0,1	311,5
São Bartolomeu II	25	0,0	0,0	0,0	0,0	0,0	70,0	3,5	73,5
Santa Cruz III	26	335,3	0,0	144,0	0,0	9,6	0,0	0,7	489,6
Cinco Ribeiras II	27	0,0	0,0	0,0	0,0	0,0	27,0	0,2	27,2
Feteira II	28	0,0	0,0	0,0	0,0	0,0	0,7	0,0	0,7
Quatro Ribeiras II	29	0,0	0,0	0,0	0,0	0,0	2,9	0,8	3,7
São Bartolomeu I	30	514,4	0,0	0,0	0,3	21,3	12,1	0,4	548,4
Fontinhas II	31	0,0	0,0	0,0	0,0	0,0	22,0	0,1	22,1
Doze Ribeiras II	32	0,0	0,0	0,0	0,0	0,0	22,7	0,4	23,1
Ribeirinha I	33	696,2	0,0	0,0	0,3	6,5	17,8	0,6	721,4
Lajes II	34	22,6	0,0	531,0	0,0	4,6	0,0	0,2	558,3
Terra Chã I	35	756,2	0,0	0,0	1,4	10,4	12,9	1,2	782,1

Cabo da Praia I	36	184,7	23,7	0,0	0,0	11,1	0,0	0,0	219,5
Santa Bárbara III	37	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Porto Judeu II	38	0,0	38,7	0,0	0,0	0,0	101,1	1,2	141,0
Terra Chã II	39	0,0	0,0	0,0	0,0	0,0	11,4	1,3	12,7
Agualva II	40	0,0	0,0	0,0	0,0	0,0	36,1	6,1	42,2
Santa Luzia I	41	714,7	0,0	0,0	0,1	2,7	0,8	0,1	718,3
São Sebastião II	42	0,0	0,0	0,0	0,0	0,0	68,1	0,0	68,2
Cinco Ribeiras I	43	182,6	0,0	0,0	0,5	22,1	14,5	0,1	219,7
Ribeirinha II	44	0,0	5,0	0,0	0,0	0,0	6,8	0,2	12,1
Serreta I	45	86,9	0,0	0,0	0,0	0,1	13,0	2,6	102,6
Fonte do Bastardo II	46	0,0	0,0	0,0	0,0	0,0	13,7	0,6	14,3
São Bento II	47	0,0	24,2	0,0	0,0	0,0	18,5	0,4	43,1
Santa Cruz II	48	14,8	0,0	0,0	0,0	0,0	58,5	1,9	75,2
Posto Santo I	49	271,9	0,0	0,0	0,4	3,2	10,8	0,4	286,6
Fontinhas I	50	413,5	0,0	0,0	1,0	32,6	26,8	1,0	474,9
Posto Santo II	51	0,0	0,0	0,0	0,0	0,0	50,4	3,0	53,4
Fonte do Bastardo I	52	331,5	0,0	0,0	14,3	8,3	17,4	0,4	371,9
Conceição II	53	0,0	0,0	0,0	0,0	0,0	0,9	0,1	1,0
Altares II	54	0,0	0,0	0,0	0,0	0,0	76,7	1,5	78,3
Basic Employment		14,640,0	100,0	685,0	54,0	472,3	1101,7	50,0	17,103

K1 – urban; K2 – industrial; K3 – base; K4 – horticulture K5 – agriculture; K6 – pasture; K7 – forest.

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